

REPORT
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Investigation of Tracking, Receiving, Recording and Analysis
 of Data from Echo Satellite

Subject of Report A Comparison of the Surface Roughness of
 Echo I and II from the Direct and Cross
 Polarized Scattering Characteristics

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A COMPARISON OF THE SURFACE ROUGHNESS OF ECHO I AND II FROM THE DIRECT AND CROSS POLARIZED SCATTERING CHARACTERISTICS

I. INTRODUCTION

In order to intelligently evaluate and predict the performance of passive satellites, such as Echo I and Echo II, in a communication link requires a detailed knowledge of the scattering characteristics of the target as well as its orbital characteristics. Even more important is a knowledge of the physical and electrical properties of the target such as shape, size, surface roughness, and complex dielectric constant. From the physical and electrical properties of the target in addition to the orbital properties, it is possible to predict the scattering characteristics of simple shapes quite accurately for the major portion of the electromagnetic frequency spectrum.

Thus ground station parameters such as frequency, polarization, transmitter power, antenna gain, modulation, etc., can be optimized to increase the reliability and performance of the communication link. The problem is complicated in the case of Echo II due to the uncertainties of the physical parameters such as size, shape, and degree of inflation obtained after injection into orbit. The physical properties of the target must be determined from the scattering characteristics which is a more complex task than the converse of this problem. From previous investigations^{1,2} it has been established that a qualitative relationship exists between the surface roughness and the polarization dependence of the scatterer. This report will be primarily concerned with the investigation of the surface roughness of Echo II, and a comparison of the roughness between Echo I and Echo II as obtained from the direct-circular and cross-circular polarized scattering characteristics at a frequency of 2260 Mc.

II. DESCRIPTION OF THE TRANSMITTING AND RECEIVING FACILITIES

A. Receiving Facility

The receiving site is located at The Ohio State University in Columbus, Ohio. The facility consists of an adaptively phased, four-

element array of solid-surface 30-foot parabolic reflectors. The antennas are focal-fed and can provide dual-linear as well as dual-circular polarizations. A monopulse feed is contained in the "master" antenna for automatic tracking and the remaining three antennas are slaved to the master antenna. Parametric amplifiers with noise figures from 2.6 to 3.0 db are contained in the feeds. Downconversion from 2260 Mc to 30 Mc is accomplished at the feed point, and the 30 Mc signals are fed by coaxial cables to the central located receiving and recording equipment. The signals are downconverted from 30 Mc to 2.8 Mc where they can be phased together and summed. The signals (4 individual plus sum) are then downconverted to 455 Kc and fed to phase-lock demodulators. The demodulation output is a dc signal which is recorded on both magnetic tape and strip charts. The experimental data contained in this report was obtained from two of the antennas and sometimes one antenna. This was accomplished by having one antenna on direct-circular polarization and the remaining antenna on cross-circular polarization, or switching one antenna periodically from direct- or to cross-circular polarization. In the latter technique the change in range to the target must be taken into account. A more detailed description of the receiving facility is contained in reference 3.

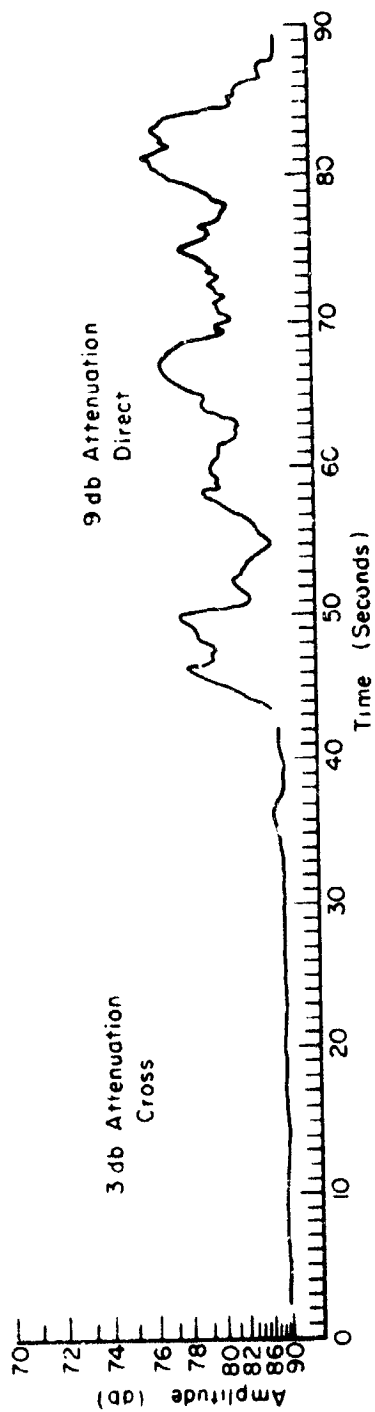
B. Transmitting Facility

The signals used for the illumination of Echo I and Echo II were provided by The Collins Radio Company, Dallas, Texas. The transmitting system consists of an azimuth/elevation mounted 60-foot diameter solid-surface parabolic reflector and a 28-foot azimuth/elevation mounted parabolic reflector. In the normal operation the 28-foot antenna illuminates the target with a radar signal at 2190 Mc, while the 60-foot antenna tracks the 2190 Mc signal and transmits a frequency of 2260 Mc with a nominal radiated power of 10 Kw. A monopulse feed is used for automatic tracking, the mode of transmission is cw, and circular polarization is employed. A more detailed description of the transmitting facility is contained in reference 4.

III. EXPERIMENTAL MEASUREMENTS

A. Results of Experimental Measurements

The results of the direct- and cross-polarized measurements are shown in Figs. 1 through 6 for the respective Echo passes. The results



Echo II 3041

Fig. 1. Comparison of direct circular and cross circular polarization scattering.

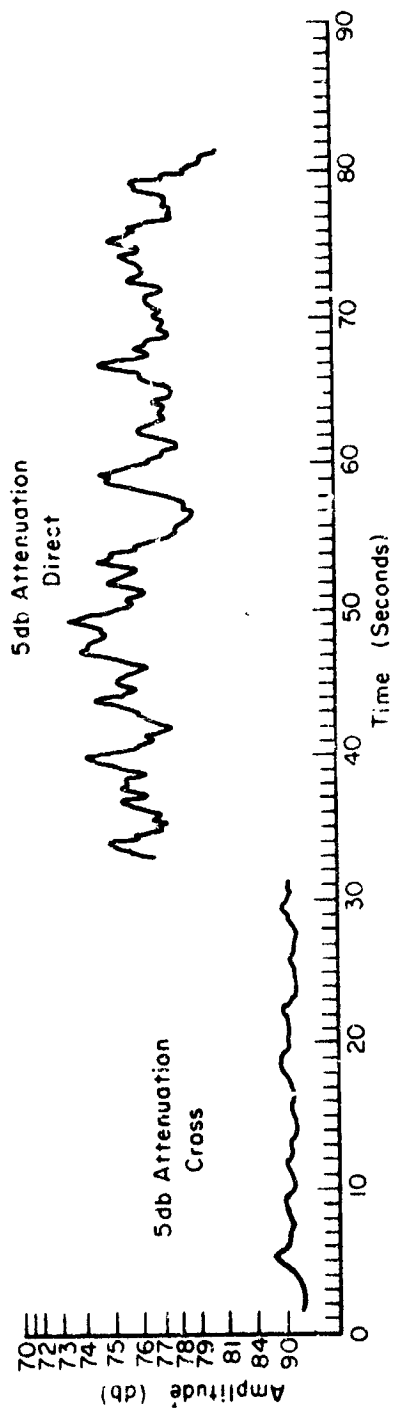


Fig. 2. Echo II 3483

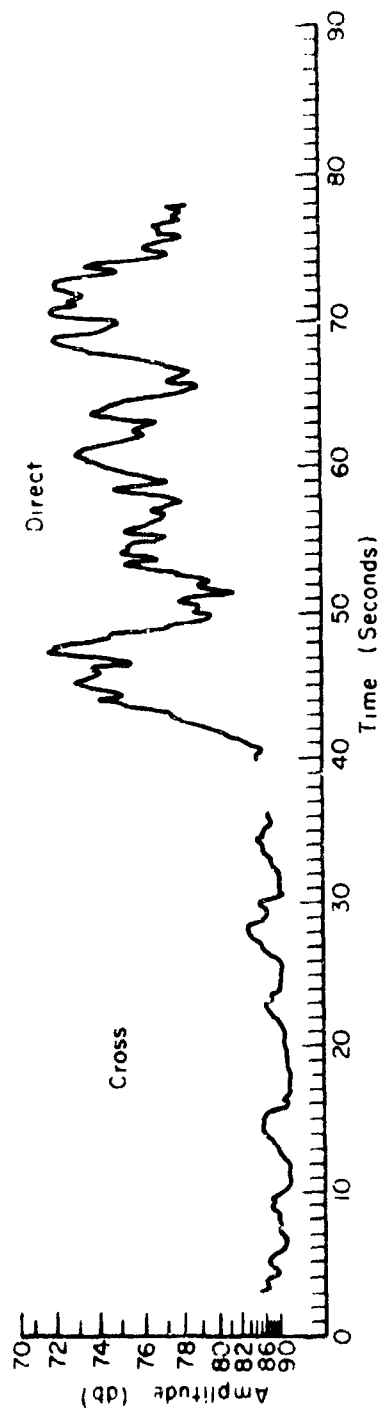


Fig. 3. Echo II 4029

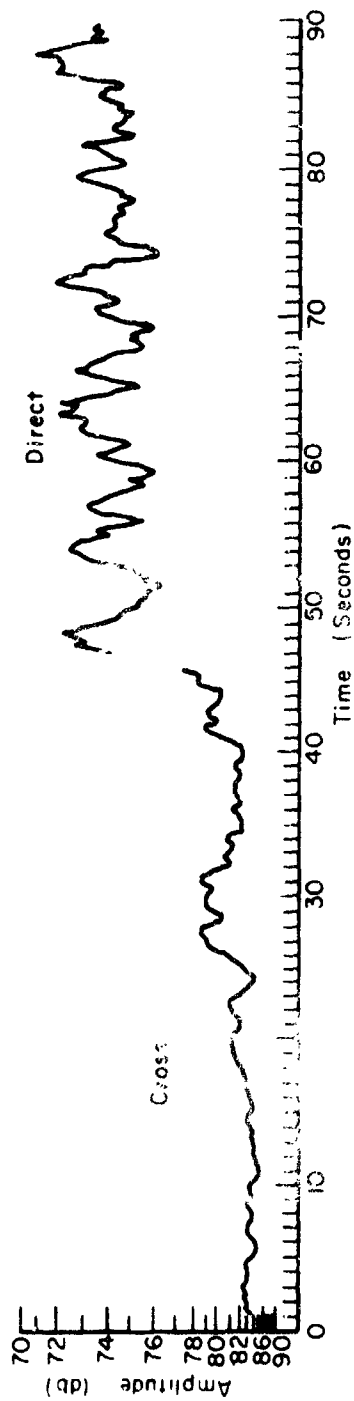


Fig. 4. Echo II 4135

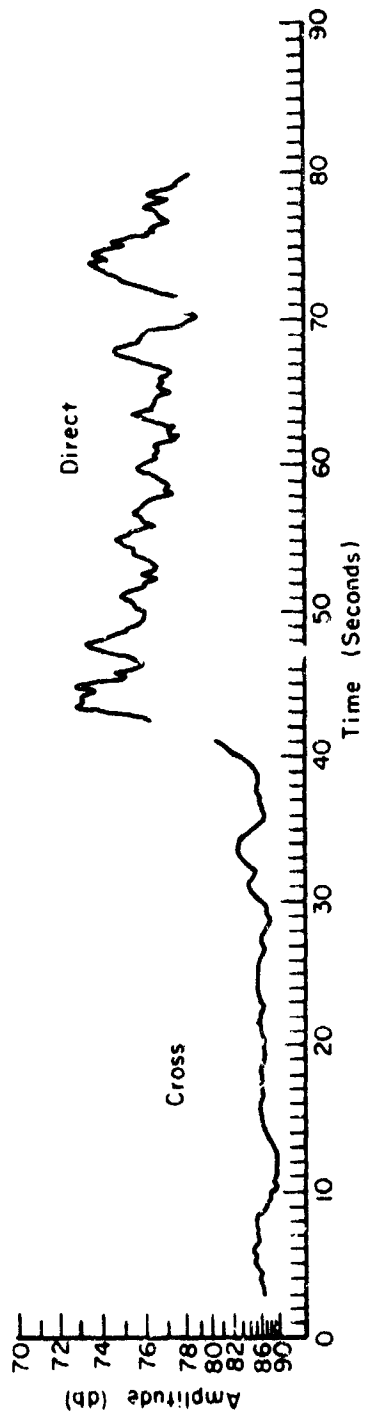


Fig. 5. Echo II 4143

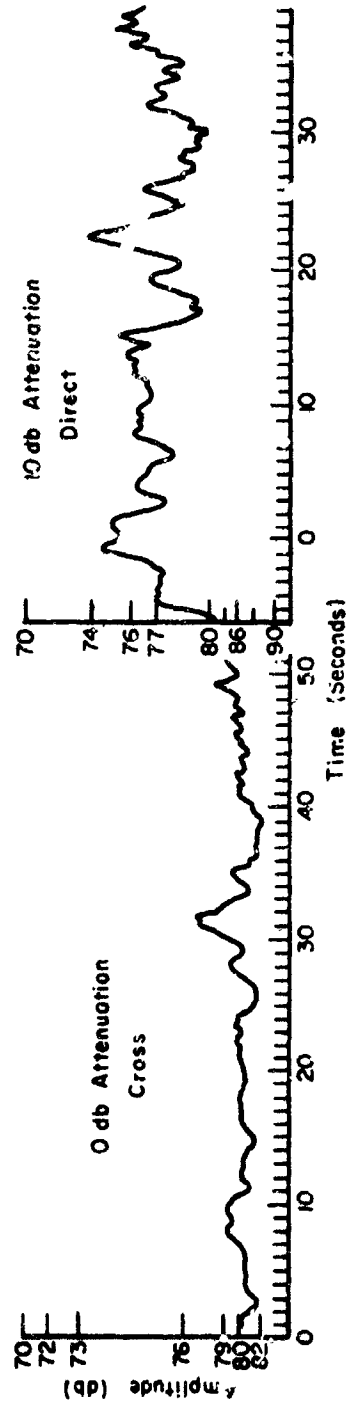


Fig. 6. Echo I 18,966

for pass numbers 3041 and 18,966 were obtained with two antennas while the remaining results were obtained with one antenna. The strip chart recordings have been integrated with a time constant of 4-seconds in order to obtain an average power level. In addition, the data was sampled at a rate of 40 samples/second for a period of 30 seconds, and an average value of received power obtained. This method enabled the nonlinearities of the receiving system to be removed. The results of these measurements are shown in Table I and compare quite favorably with those obtained from the integrated strip-chart recordings. The accuracy of the measurements shown in Table I is approximately ± 2 db. The effects of the transmitter ellipticity have not been taken into consideration because of the uncertainty to date of this parameter. However, it has been reported that the ellipticity is less than 2 db at a frequency of 2260 Mc.

TABLE I
RATIO OF CROSS-CIRCULAR TO DIRECT-CIRCULAR
TOTAL SCATTERING CROSS-SECTION

Echo II	3041	~ 14 db
Echo II	3483	16 db
Echo II	4029	11,12 db
Echo II	4135	9 db
Echo II	4143	9,10 db
Echo I	18,966	11 db

The results of the measurements show that from pass 4029 to the present, the difference between the cross- and direct-polarized scattering has remained fairly constant with a slight downward trend possibly indicating a slight increase in surface roughness. However, the results from pass 3483 shows a considerable difference in the cross-polarized return and would indicate that the roughness of the balloon has increased significantly. In order to obtain a longer period of the history of the cross-polarized scattering the results from an earlier pass (#3041) has been included, even though the data is questionable, because the cross-polarization return is very close to the noise level of the system. It is unfortunate that no cross- and direct-polarization measurements were made during the early life of Echo II. From the results of the measurements shown in Table I including passes 3041 and 3483 it can generally be concluded that the roughness of Echo II has increased. This effect would be anticipated as the balloon has probably been punctured repeatedly by foreign objects during this period

of time. The large difference noted between pass 3483 and succeeding passes should not be construed as definitely showing that something has happened to the balloon during that interval of time since sufficient data is not available on succeeding passes and there is a complete lack of information during the early life of Echo II. The one measurement obtained from Echo I indicates a degree of roughness very close to that obtained for Echo II. This compares quite favorably with the amplitude fading statistics obtained during earlier passes of Echo II and Echo I.⁵

B. Comparison of Measurements With Known Surfaces

In addition to the direct- and cross-polarization results contained in this report, the fading rates and amplitudes have been observed.⁵ It has been found that on the average the amplitude fading is between 5 db and 10 db. At times fades in excess of 20 db have been recorded. The depth of fades is primarily due to surface roughness and the rate of fading (in this case up to 250 cps) is due to relative motion between the target and the receiver. Taking at face value the work in reference 6 concerning the effects of surface roughness of a sphere upon the scattering characteristics, it was shown that the peak amplitude deviation was 4 db for a roughness of $d/\lambda = 5 \times 10^{-2}$ and $w/\lambda = 2 \times 10^{-1}$ where

d = depth or height of bump
w = width of bump
 λ = wavelength.

Scaling the roughness to 2260 Mc, values of d and w would correspond to 0.66 cm and 2.64 cm respectively. The amplitude fades greater than 20 db obtained for Echo II and Echo I indicate the roughness is considerably greater than the above values. From previous measurements involving the scattering characteristics of terrain as a function of polarization² it has been found that for a roughness parameter $\xi = D/\lambda = 0.33$, the difference between cross-circular and direct-circular polarization was 8 db where

D = diameter of particles or holes
 λ = wavelength.

Scaled to 2260 Mc this would correspond to a roughness parameter of 4.4 cm. In the case of the terrain the surface was not a near perfect conductor as is assumed for Echo II. The effects of penetration into

the surface tends to increase the depolarization of the reflected signal. Hence if the surface was a perfect conductor the difference between the direct- and cross-polarization return would have been greater. The main point of these comparisons is to establish some limits of roughness from the measurements obtained for Echo I and Echo II.

IV. CONCLUSIONS

It could be concluded from the results of the direct-circular and cross-circular polarization measurements the surface roughness as measured at 2260 Mc is increasing. Because of the lack of knowledge concerning the polarization of the reflected signal and surface roughness, it is not possible to establish a definite value for the surface roughness of Echo II with the experimental measurements obtained at a single frequency. However, from the results of these measurements it may be concluded that both Echo I and Echo II is a rough scatter at 2260 Mc. From a comparison of the polarization results obtained from Echo II and known surfaces, a roughness parameter greater than 5 cm would not be inconsistent with present theory and the results of experimental measurements. It should be pointed that analysis of the polarization measurements is hampered by the lack of information concerning the polarization effects at other frequencies. It may prove possible to establish a definite value for the surface roughness of Echo II when the data have been completely analyzed and information from other frequencies become available.

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